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Revision 0

HANFORD SITE LOW EXPOSURE PIPELINE REPAIR USING A NON-METALLIC COMPOSITE SYSTEM

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company

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ABSTRACT

At the Department of Energy, Richland Operations (DOE-RL) Hanford site in eastern Washington, a 350 mm (14 inch) diameter high density polyethylene (HDPE) pump recirculation pipeline failed at a bonded joint adjacent to a radiologically and chemically contaminated groundwater storage basin. The responsible DOE-RL contractor, CH2MHill Plateau Remediation Company, applied a fiberglass reinforced plastic (composite) field repair system to the failed joint. The system was devised specifically for the HDPE pipe repair at the Hanford site, and had not been used on this type of plastic piping previously. This paper introduces the pipe failure scenario, describes the options considered for repair and discusses the ultimate resolution of the problem.

The failed pipeline was successfully returned to service with minimal impact on waste water treatment plant operating capacity. Additionally, radiological and chemical exposures to facility personnel were maintained as low as reasonably achievable (ALARA). The repair is considered a success for the near term, and future monitoring will prove whether the repair can be considered for long term service and as a viable alternative for similar piping failures at the Hanford site.

INTRODUCTION

In February of 2009, a radiologically and chemically contaminated Liquid Effluent Retention Facility (LERF) storage basin pump recirculation pipe failed at a bonded joint on a mitered elbow. The mitered elbow is composed of two sections of 350 mm (14 inch) diameter high density polyethylene (HDPE) pipe, bonded together at an angle of approximately 20 degrees. The piping is located outdoors and is not protected from the elements. The bond failed approximately 20 years after original installation. The pipe could not be successfully repaired using approved site bonding procedures, and an alternate repair method was developed, implemented, tested and placed in service. The alternate repair method was performed in accordance with ASME PCC-2-2008 (Reference 1).

This paper describes a non-standard repair of the failed HDPE bond using a proprietary fiberglass reinforced plastic (FRP) composite system.

FAILURE HYPOTHESIS

The hot-gas bonded joint failed at the bond fusion zone. The failure was completely through-wall for about 50 percent of the circumference of the pipe.

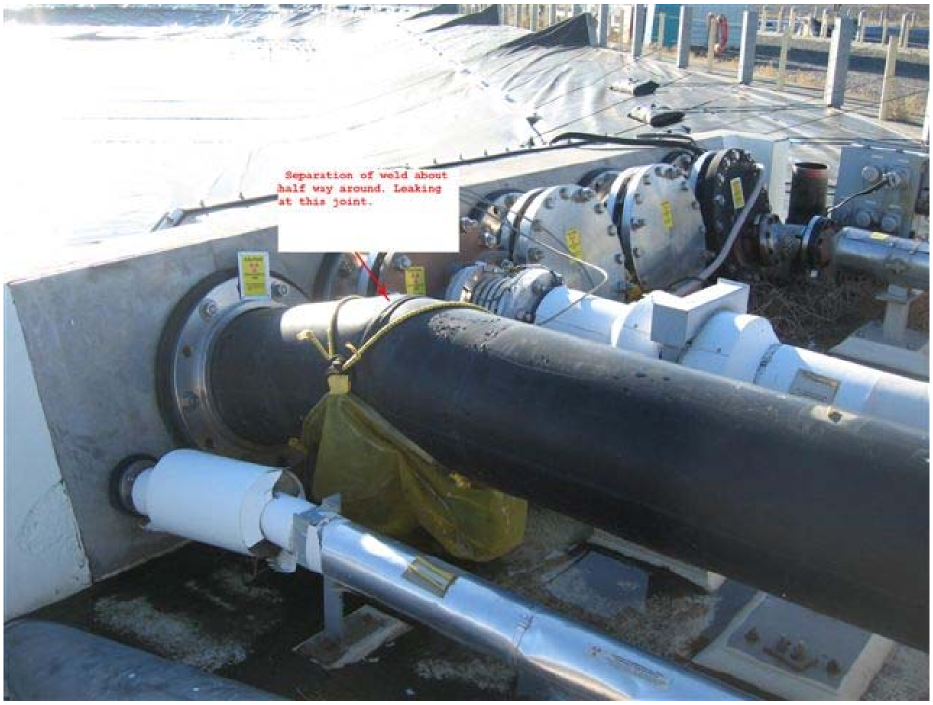

Fig. 1 – Location of bond failure on HDPE recirculation pipe

The flow rate in the pipe is very low relative to the pipe diameter, and atmospheric pressure channel flow exists. Therefore, no dynamic pipe loads exist.

Cyclical thermal pipe expansion overstressing the vulnerable bond fusion zone is considered the most likely cause of the failure. Thermal expansion of HDPE was an original design concern and was accounted for in the design of supports. The pipe up and downstream of the elbow is well supported. An axially and radially fixed support is located about two feet downstream of the elbow, and two radially fixed pipe supports are located immediately upstream and five feet upstream. An expansion joint is also installed upstream of the two upstream supports. The pipe is therefore free to expand thermally upstream. However, day to night temperature swings on the Hanford site average 17° C (30°F), and much larger differentials exist between summer and winter temperatures. The daily and seasonally cyclic nature of the expansion is likely to have fatigued the bonded joint at the elbow, resulting in a failure of the bond. Based on the appearance and location of the failure, it is also likely that the original bonded joint did not have adequate adhesion.

An additional likely contributor was additional live loads applied to the pipe by personnel clambering over the line during work evolutions at the basin.

DESCRIPTION OF STANDARD PIPE REPAIRS

Hot-Gas or Fusion Bonding

The piping was originally constructed in accordance with ASME B31.3, "Process Piping Code" and the construction pipe specification. There is a Hanford hot-gas bonding procedure (Ref. 2) that is an appropriate standard repair procedure. It was originally anticipated that this procedure would be used to perform the repair. Other possible fixes included removal and replacement of the affected elbow using a fusion-bonding technique.

Pipe Replacement

Removal of the entire length of failed pipe and replacement with a new section of pipe bonded off-site is another possible pipe specification-compliant repair method. Other possible fixes included installation of a flanged shop-fabricated piece.

REASONS WHY A COMPOSITE REPAIR WAS SELECTED

Low Severity of Service

The failed 350 mm (14 inch) pump recirculation line flows well under 300 liters per minute (80 gallons per minute) of ambient temperature water in normal operation, and up to 1135 liters per minute (300 gallons per minute) during occasional test evolutions. These flows are very small relative to the pipe size and downward slope back to the basin. Because of this, the pipe is less than 50% full at all times, and operates at atmospheric pressure. Therefore, pressure and temperature service on this line is not severe, and there are no reaction forces or hoop stresses due to internal pipe pressure. An engineered composite repair is believed to have substantial probability of long term success.

Impact of Failure on Plant Operations

Operational problems were a primary driver for considering this repair. Expeditious repair of the line was highly desirable in order to eliminate operational difficulties. The proposed repair would result in superior "return to service" time. Operational impacts of the failure are described in the paragraphs below.

LERF Basin 43 is the main feed basin for the 200 Area Effluent Treatment Facility (ETF). The ETF continuously processes water with low levels of radiological and chemical contamination located in groundwater and other Hanford site waste water sources. Feed for the basin comes from a variety of groundwater sources.

The contaminated water is pumped from the LERF basin to the ETF using a 7.46 KW (10 HP) submersible pump. Pump flow to the ETF is flow controlled to maintain the influent (Surge) tank level constant, for process chemistry control purposes. Since the automatically controlled flow may be less than the pump manufacturer's minimum required flow, a recirculation flow path is provided using a 350 mm (14 inch) HDPE basin return line to ensure adequate pump flow. This is the line that failed. To preclude potential leakage to the environment, the line was isolated.

Because pump flow needed to be maintained above minimum flow, the Surge Tank level constantly rose with the LERF basin pump in operation. This resulted in the need for a batch mode of operation, which creates a burden on the control room operator to constantly monitor and control level. In addition, reverse osmosis treatment system operation is optimized for a constant feed tank conductivity. Stable conductivity is not achievable during the batch mode of operation.

Radiological Constraints

The recirculation line normally contains radioactively contaminated water. Physical removal of HDPE weld and pipe materials necessary to re-bond the pipe, using hot-gas bonding, is a contamination control problem. Hot-gas bonding on a potentially contaminated pipe was a concern to the facility radiological control and safety organizations. The proposed repair procedure is considered superior from an ALARA (As Low As Reasonably Achievable) exposure perspective.

Hot-Gas Bonding Physical Constraints

It was originally anticipated that hot-gas bonding would be used to repair the line. A bonder was qualified for the Hanford site welding procedure. During the qualification, it became clear that physical constraints at the actual failure site would prohibit use of repairs where hot gas bonding was required. The bonder determined that a minimum of 46 cm (18 inches) of clearance was required all around the pipe in order to adequately position the hot-gas gun and HDPE rod. The available clearance below the pipe is about 31 cm (12 inches), precluding this method of repair. This restriction also prohibited replacement of the failed elbow with a flanged replacement elbow, since field bonds for flanges on existing piping could not be made.

Pipe Replacement Constraints

The total length of 350 mm (14 inch) diameter pipe is approximately 34 meters (110 feet). The piping contains several bonded joints along that length. The pipe is routed through a concrete thrust/support block just downstream of the failed weld, and continues under a polyethylene basin cover for about 31 meters (100 feet). Removal and replacement of the piping would entail temporary removal of the 26.5 million liter (7 million gallon) basin cover, pipe removal, shop fabrication of the large spool piece, and reinstallation of pipe and basin cover. Replacement of the entire length of piping is a significant scope of work. This large pipe replacement job would not have allowed the plant operations department to successfully maintain required production capacity.

COMPOSITE REPAIR SYSTEM REPAIR DESCRIPTION

The selected repair materials and methodology were provided by PowerWrap, LP. Two engineered composite (FRP) systems were applied to the piping, around the failed bond. The first consists of an epoxy wetted Kevlar®/E-Glass yarn fabric that is wrapped around the repair area as a base matrix. The second is a fabric that is factory impregnated with a water-activated polyurethane resin. The wetted fabric is wrapped over the cured base matrix. The two systems provide a high strength enclosure for the failed bond.

Specifically, the HPDE piping exterior was roughened in the area of the repair, to aid in bonding between the pipe and repair materials. The final pass of the existing bonded joint was also sanded smooth, to eliminate possible void spaces.

The pipe was primed with a "Standard Matrix" epoxy for a distance of 10 to 13 cm (4 to 5 inches) on either side of the failed bond, and 14 meters (45 feet) (about three layers) of the epoxy impregnated base matrix was wrapped tightly around the pipe joint. A temporary band of plastic wrap was applied around the installed base matrix during curing. This plastic wrap aids in adhesion by compressing the fabric matrix against the HDPE pipe, and helps form a smooth exterior finish. After the base matrix was fully cured, the plastic wrap was removed, and the matrix was lightly sanded and buffed to remove any sharp edges.

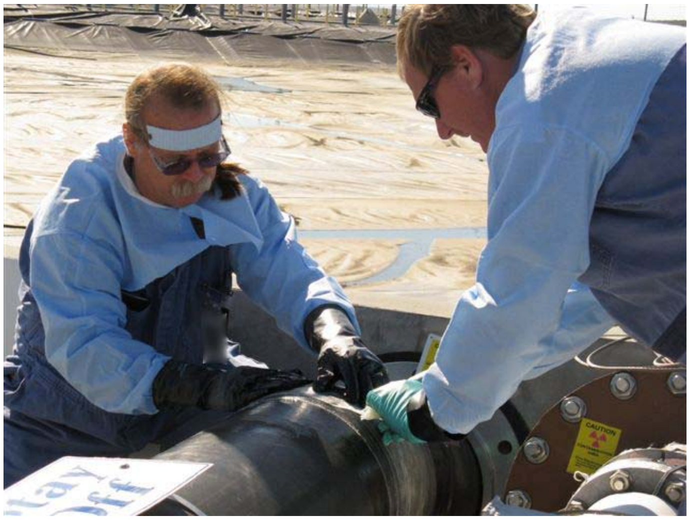

Fig. 2 – Application of epoxy impregnated base matrix to HDPE elbow

In preparation for the application of the wetted final layer, a specific primer was applied to the repair area out to about 30 cm (one foot) past the base matrix wrapped area on each side. The water-activated fabric was wetted and wrapped over and beyond the base matrix, four layers thick.

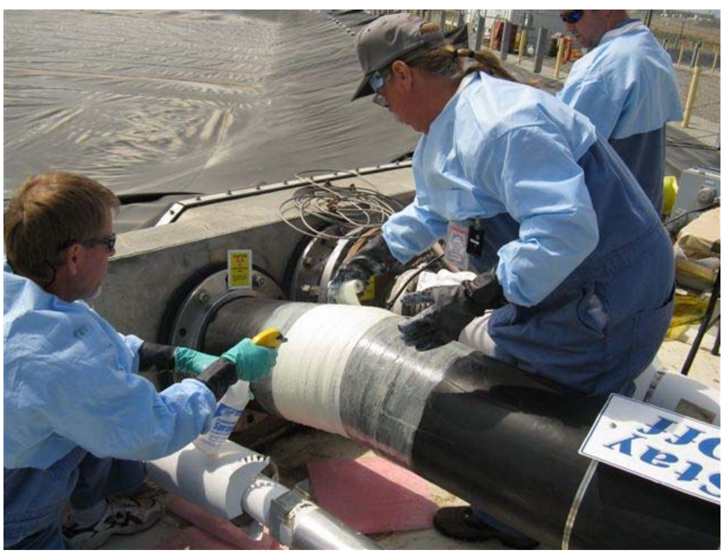

Fig 3 – Application of final layer as water activated fabric is wetted

Plastic wrap was again used, and removed after curing, about 24 hours later. Rough areas were sanded smooth, and a final compatible paint coating was applied over the entire area, as a protection against damage from UV. An initial service leak test was successfully performed and the recirculation line was returned to service in June of 2009.

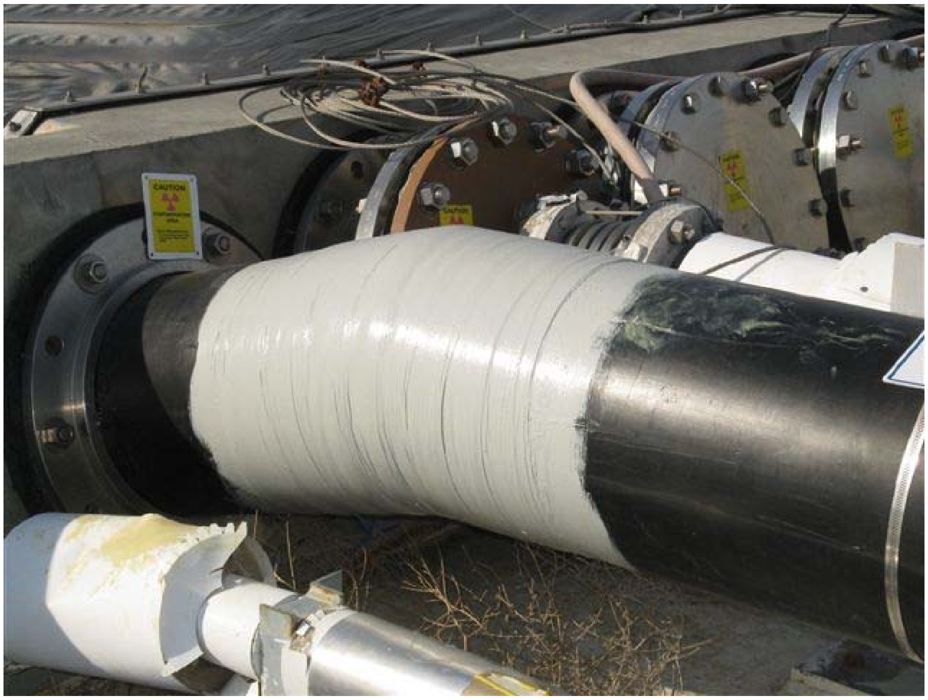

Fig. 4 – Final repair after paint coating

ADDITIONAL STEPS TAKEN TO PROTECT PIPING

In addition to applying a coating for UV protection, the repaired area was covered with ceramic fiber blanket insulation for additional UV protection. “Stay Off” signs have been placed on the piping to limit “personnel” loading on the line. Four times a year, the insulation will be removed and a formal inspection for signs of failure or leakage will be performed.

PROOF OF CONCEPT PRESSURE TESTING

The repair procedure was first performed on a test section of 350 mm (14 inch) HDPE piping. Two 30 cm (12 in) long pieces of pipe were joined by hot-gas bonding. The pipe ends were sealed with HDPE plugs which were also bonded. This test piece was used to qualify the proposed composite repair.

A cut was made through the hot-gas bonded joint, almost all the way around the pipe, and the pipe pieces were spread apart so that a gap was created. A composite repair was made as described above. The required construction hydrotest pressure for the pipe, based on the original construction piping specification is three feet of water or 9 kPa (1.3 psi) held for 15 minutes. A value of 34 kPa(5 psi) was conservatively selected for this proof-of-concept test. The hydrotest was performed, pressure was held at 34 kPa (5 psi) for 15 minutes, and no leakage was observed from the bonded repair.

EXPECTED LIFE

According to the manufacturer, composite life varies greatly depending on application. Long term tests performed by the manufacturer indicate that the final matrix will retain 50% of its strength after 50 years. Epoxy systems such both types of materials have been in use in various applications for decades. Service life for this repair should be enhanced by the lack of internal pressure in the pipe during operation.

Because of the uncertainty associated with design life of these systems in our application, quarterly inspections as described above will continue to be performed, in order to monitor the long term condition of the repair.

LONG TERM STRATEGY FOR REPAIR

The facility intends that this repair be permanent, pending the results of regular inspections. If the repair fails in the future, a cost benefit analysis will be performed on repair options available at that time. Furthermore, the facility intends that this repair procedure be applicable to two other similar HDPE recirculation lines on two identical basins. As a point of interest, in November of 2009, a second identical failure on one of the other two basins was identified.

REFERENCES

1. ASME PCC-2-2008, "Repair of Pressure Equipment and Piping", Article 4.2
2. Hanford Welding Procedure PBPS-0004, "Hot Gas Bonding of Thermoplastic Plastics", Rev. 1, 2004